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RESPONSE OF A BURNING PROPELLANT SURFACE TO EROSION TRANSIENTS

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## SUMMARY

During the second quarter, emphasis has been placed on critically evaluating our experimental and theoretical programs in order to assess their relation to published Russian work which apparently contradicted our analysis. This apparent discrepancy has been successfully resolved, for the Russian model appears to be for homogeneous propellants, and ours is for heterogeneous propellants.

## EXPERIMENTAL STUDIES

### Solid-Phase Exothermic Reactions of Propellants

As a result of our theoretical analysis of combustion instability, a more extensive study of solid-phase reactions has been initiated using differential thermal analysis. The importance of surface-coupled reactions in determining the stability bounds imposed upon our combustion model was developed in some detail in Quarterly Report 1.

Since our past experimental studies determined a relationship between burning rate and chamber pressure which represents a stability limit, it appeared desirable to investigate the effect of pressure on the results of differential thermal analysis experiments with selected propellants. This has been accomplished with ammonium perchlorate (both as-received and high purity), potassium perchlorate, and propellants formulated with a hydroxy-terminated polybutadiene and toluene diisocyanate. Under a nitrogen pressure of 500 psig, the AP thermograms show significant changes; the exotherm signifying deflagration is lowered from about 450°C to the range 300 to 325°C. When potassium perchlorate is treated similarly the pressure effect is far less pronounced, although the decomposition exotherm definitely starts at a lower temperature. A possible explanation for this type of behavior is that the concentration of the decomposition products is increased, and the local heat release is increased.

Propellants containing AP were subjected to differential thermal analysis from atmospheric pressure to 1000 psig. At atmospheric pressures two distinct decomposition exotherms peak at about 360 and 415°C. At 250 psig a third exotherm appears at 450°C. As pressure is further increased to 500 psig, these three exotherms tend to merge together. At 1000 psig the broad exotherm observed at 500 psig has become much narrower and peaks at a lower temperature, 340°C.

### Spectroscopic Probe of Propellant Combustion Zone

An in-house program aimed at developing a means of identifying combustion species during transient instabilities has led to the development of a technique using a Vidicon tube to scan, in real-time, the spectrum from either a grating or prism. An emission scan from 3000 to 8000 Å can now be made in 60 microseconds. The emission spectra of an 80/20 AP/polyurethane propellant burning at 500 psig pressure shows only two luminous bands, one extending from 6150 to 6500 Å, the other from 5750 to 6000 Å. Within these bands several lesser bands of high intensity appear. Identification of the combustion species responsible for the observed spectra has proved to be difficult because of the general lack of published work identifying the nature of spectra obtained at high temperatures and pressures. It is known that spectral bands both broaden and shift under these conditions. We are concerned also that adsorption by the combustion gases under pressure and at high temperature may modify the emission spectra considerably. As a result more definitive experiments have been undertaken to investigate these problem areas. We are also developing alternative methods to extend the range of the Vidicon type instruments into the far infrared region between 1 and 5 microns.

## THEORETICAL STUDIES

Our theoretical studies were primarily directed toward composite propellants, and they have confirmed that both burning rate and solid-phase reactions are important parameters. The model encompasses combustion phenomena related to both the binder and oxidizer and assumes an energy release profile which can account for both solid-phase and gas-phase reactions.

The significant conclusion of the preliminary analysis for composite propellants was that heat release in the solid phase could promote instability. However, Russian work on combustion has suggested that heat release in the solid phase would stabilize combustion.

Our knowledge of past Russian work in the double-base propellant field, coupled with our experimental stability data on double-base propellants, suggested that the Russian analysis was related to homogeneous double-base propellants. A recent examination of pertinent Russian papers showed that their relatively simple model in fact does use a single controlling activation energy concept; this rate factor may be related, for example, to the surface decomposition of nitro-cellulose. The conclusions reached by the Russians appear quite valid for the model they use, which appears adequate to explain the behavior of double-base propellants.

## FUTURE WORK

Our future work will aim at improving the theoretical model and clearly identifying the specific chemical processes involved in the different couplings observed for both composite and double-base propellants. It is hoped that a general theory will ultimately evolve which accounts for chamber fluid mechanics as well as propellant response.

To provide a clearer picture of the detailed mechanisms of the combustion process, an effort will be made to develop improved experimental techniques. Particular emphasis will be given to spectroscopic probing of the propellant combustion zone.

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13. ABSTRACT

A review of the past quarter's activit. on combustion instability is given. In the experimental work a study of solid phase exothermic reactions is being performed. An attempt is also being made to study the gas phase reactions occurring at the surface during unstable burning using real time spectroscopy. (A rapid scan of 60 $\mu$  sec to study the 2 millisecond disturbance.)

A successful result has attended our comparison of the SRI theoretical combustion model with that of the Russians. The SRI model when simplified can be related to double base propellants and closely parallels the Russian's analysis. Our analysis predicts the opposite stability characteristics that we have observed experimentally for composite and double base propellants.

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